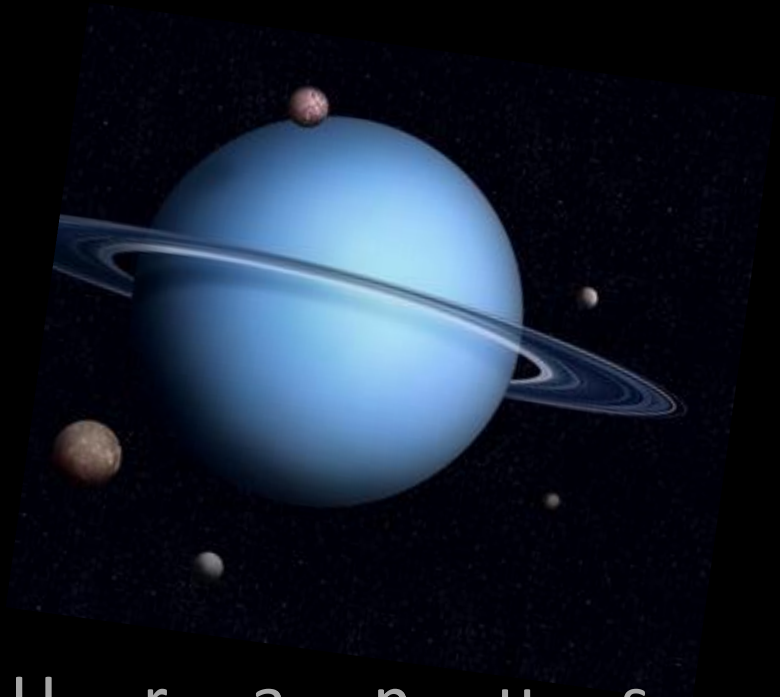
Innovative Flagship Mission Concept Studies:

- *Uranus -Tempest*
- *Enceladus - Ark*
- *Venus - Dynamo*

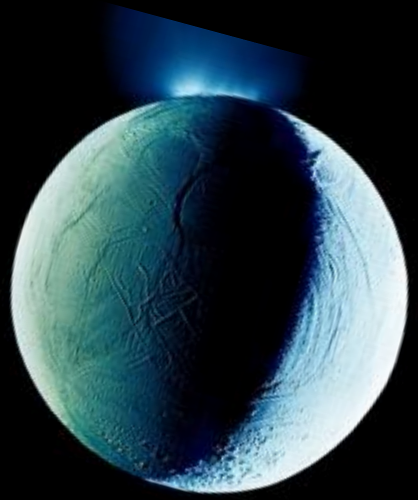
Jason Hofgartner, Mark Hofstaeder, Sue Smrekar, Jeff Hall, John Brophy, Art Chmielewski, Bill Frazier, John Elliott, Alex Austin, James Cutts, Raul Polit-Casillas, Kim Reh, Brian Wilcox, Damon Landau

Jet Propulsion Laboratory
California Institute of Technology

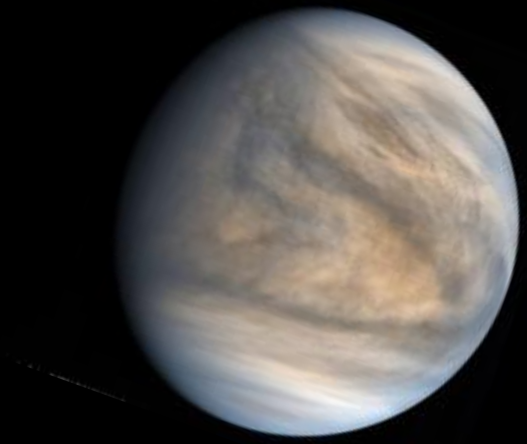
Innovative Flagship Mission Concepts



U r a n u s
Tempest



E n c e l a d u s
Ark



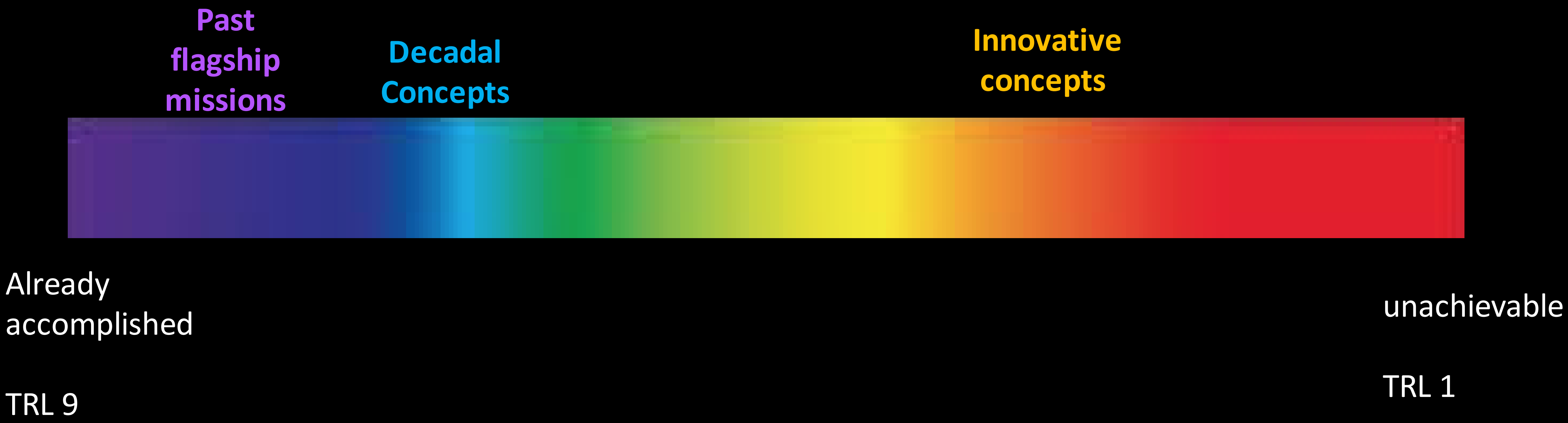
V e n u s
Dynamo

Pre-Decisional Information – For Planning and Discussion Purposes Only

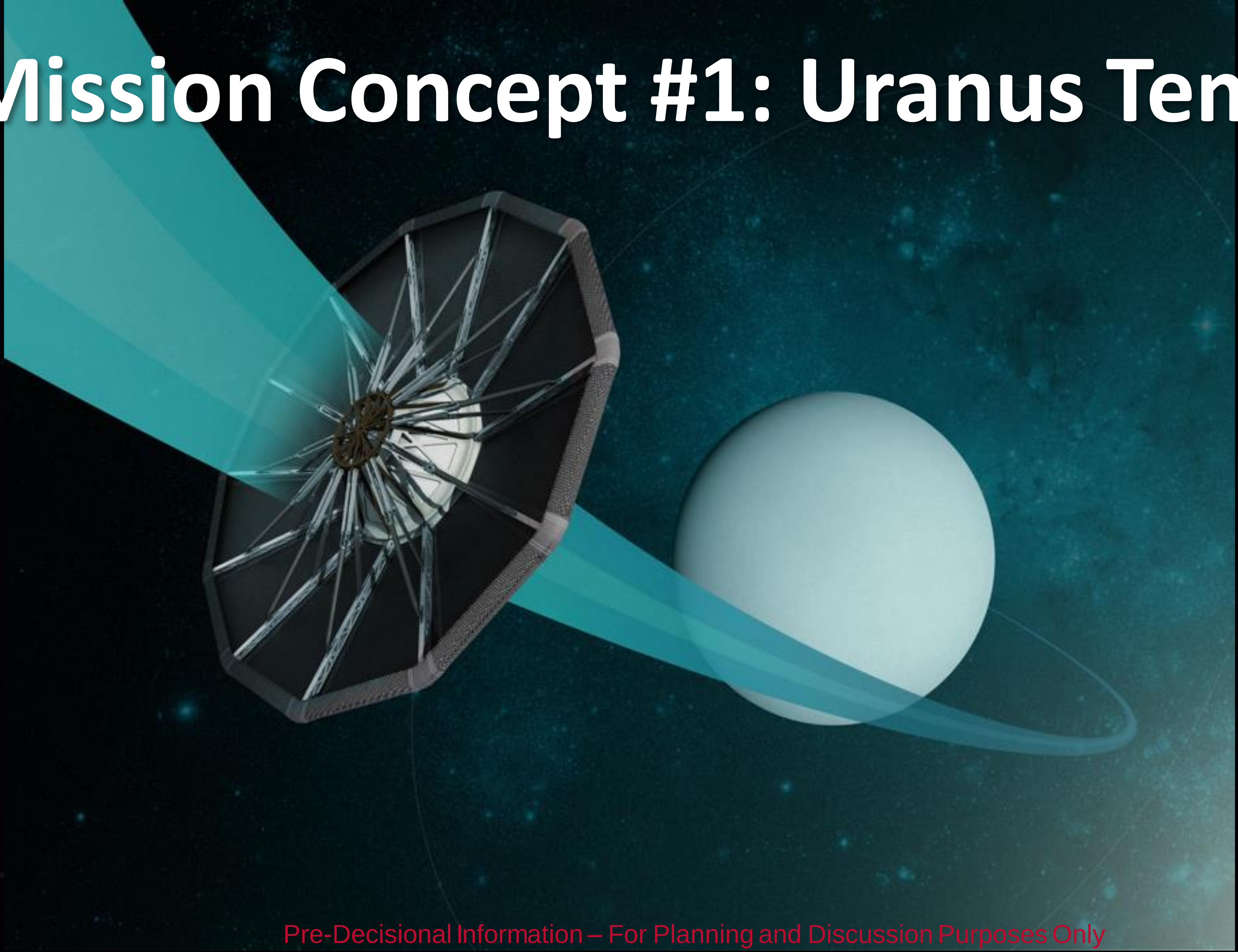
Mission Concept Innovation Spectrum

Flagship missions tend to be conservative and new technology averse. The following innovative concepts accomplish previously unachievable science with use of new technology.

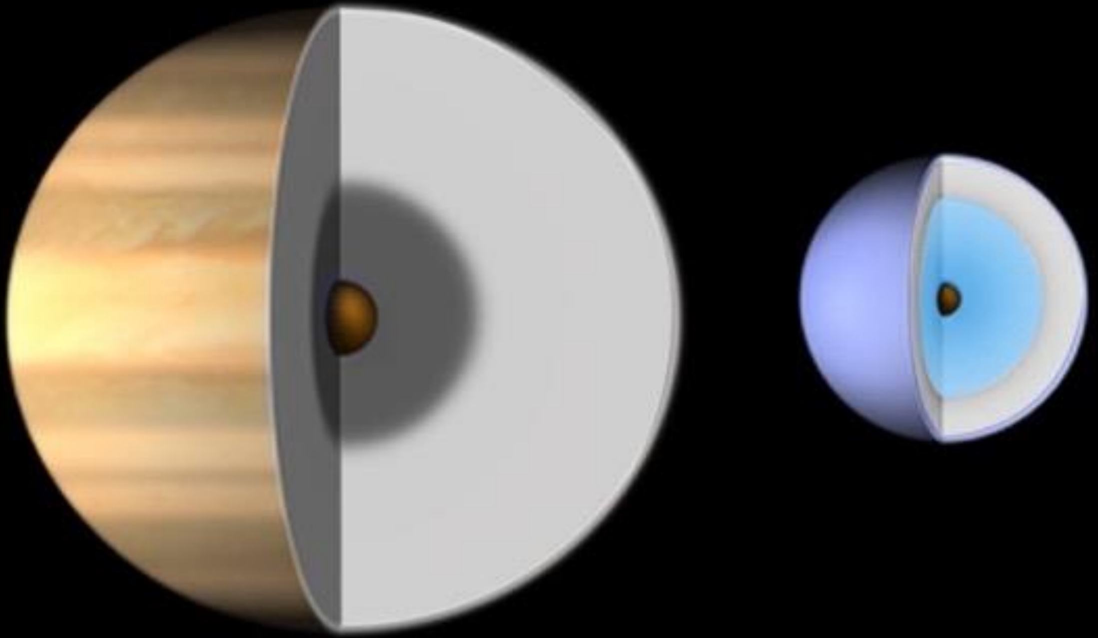
New technology content

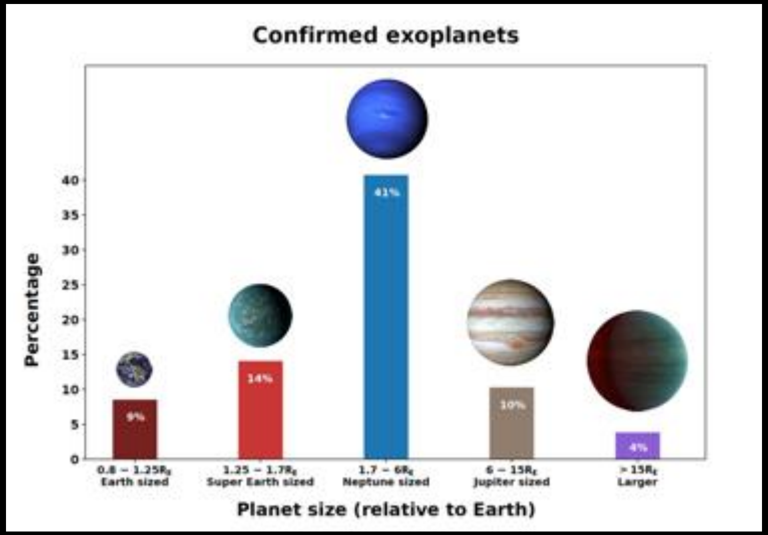


Mission Concept #1: Uranus Tempest



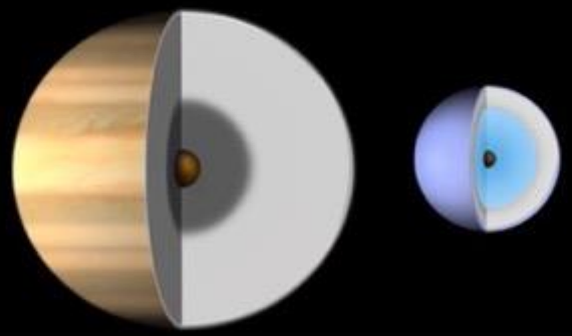
Why Study Uranus?





What is Important Uranus Science?

From the NASA Pre-Decadal Mission Study



Highest Priority
- Interior structure of the planet.
- Bulk composition (including isotopes and noble gases).

Planetary Interior/Atmosphere
- Planetary dynamo.
- Atmospheric heat balance.
- Tropospheric 3-D flow.

Rings/Satellites
- Internal structure of satellites.
- Inventory of small moons, including those in rings.
- Ring and satellite surface composition.
- Ring structures and temporal variability.
- Shape and surface geology of satellites.

Magnetosphere
- Solar wind-magnetosphere-ionosphere interactions and plasma transport.

Uranus Tempest Science Payload Baseline

Tempest accomplishes all priority science plus previously thought to be unachievable science.

Orbiter

- Accelerometer/gravity gradiometer
- WAC/NAC
- Vis/NIR imaging spectrometer
- Magnetometer w/ 10 m boom
- USO
- Radio/Plasma waves with Langmuir probe
- Low- and High-energy plasma particles
- Energetic neutral atoms
- Thermal-IR imager with Vis/IR bolometer
- Dust detector
- UV imaging spectrometer
- Microwave sounder
- Radar sounder
- Topographic radar
- Mid-IR imaging spectrometer
- Dust mass spectrometer
- Doppler imager
- Mass spectrometer

Atmospheric Probe

- Mass spectrometer
- Pressure and temperature
- Camera-radiometer
- Photometer
- USO

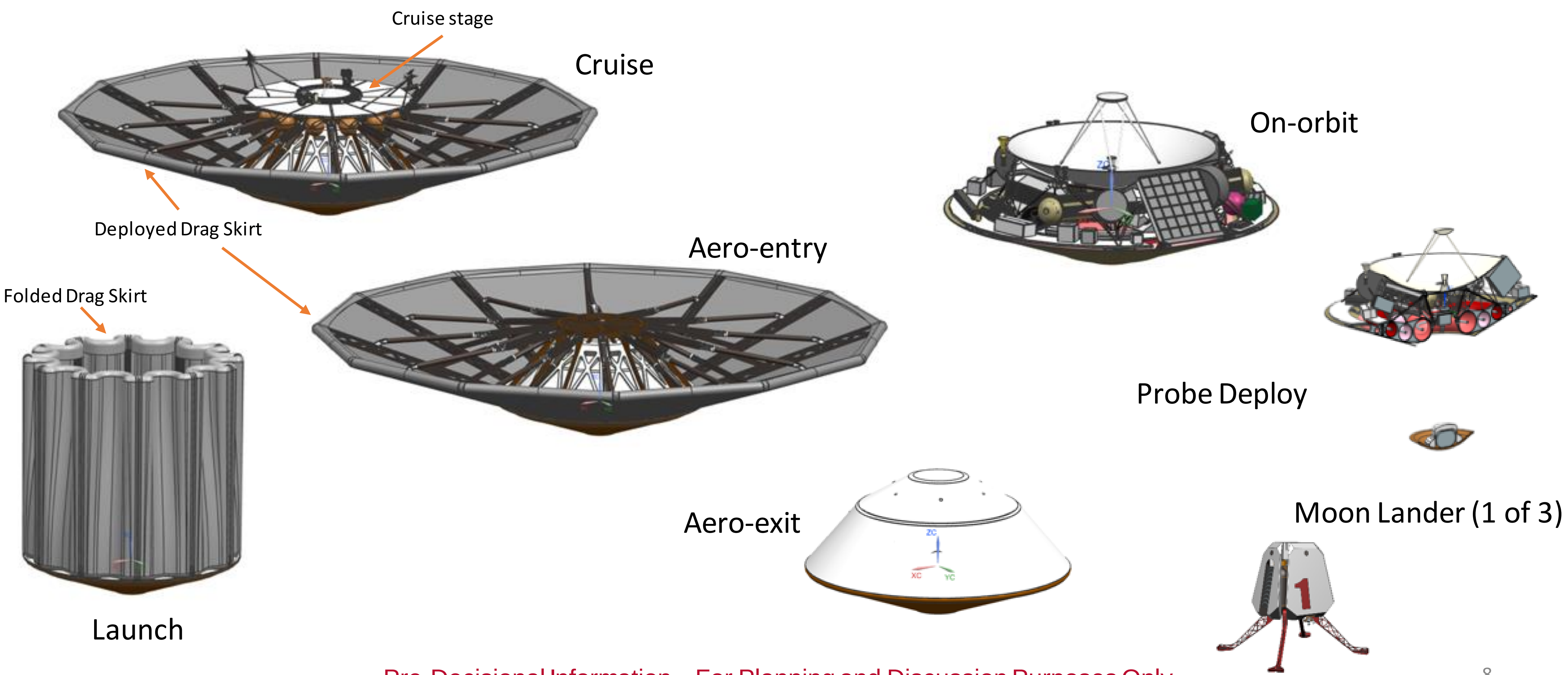
Deep Probe

- Mass spectrometer
- Pressure and temperature

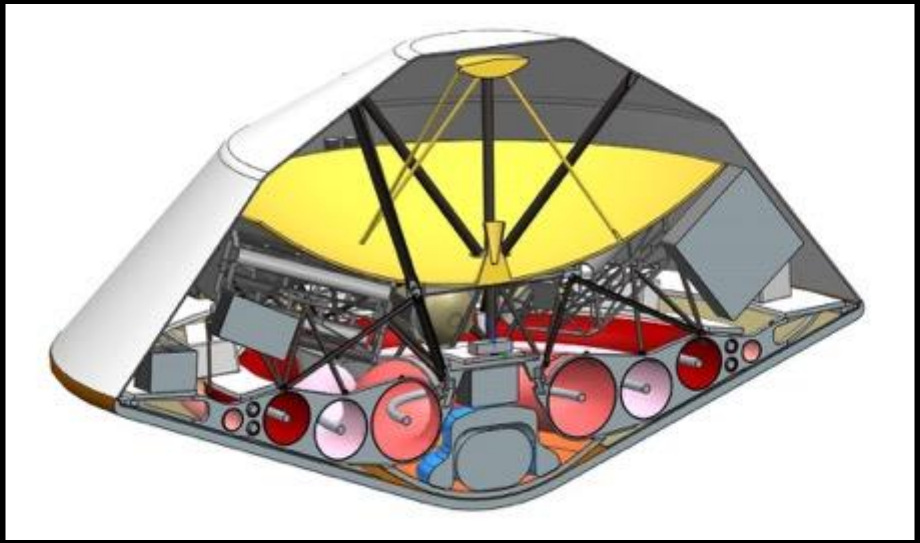
Landers (3 of them)

- Seismometer
- Cameras
- Mass spectrometer

Flight System Configurations



Uranus Tempest Spacecraft Elements Baseline



Picture of the shallow probe

Shallow probe:
stays on parachute,
lasts for ~90 min until
reaches 20 bar

Deep probe:
Titanium sphere hosting an
ion spectrometer drops
without parachute and
survives at least until 1000 bar

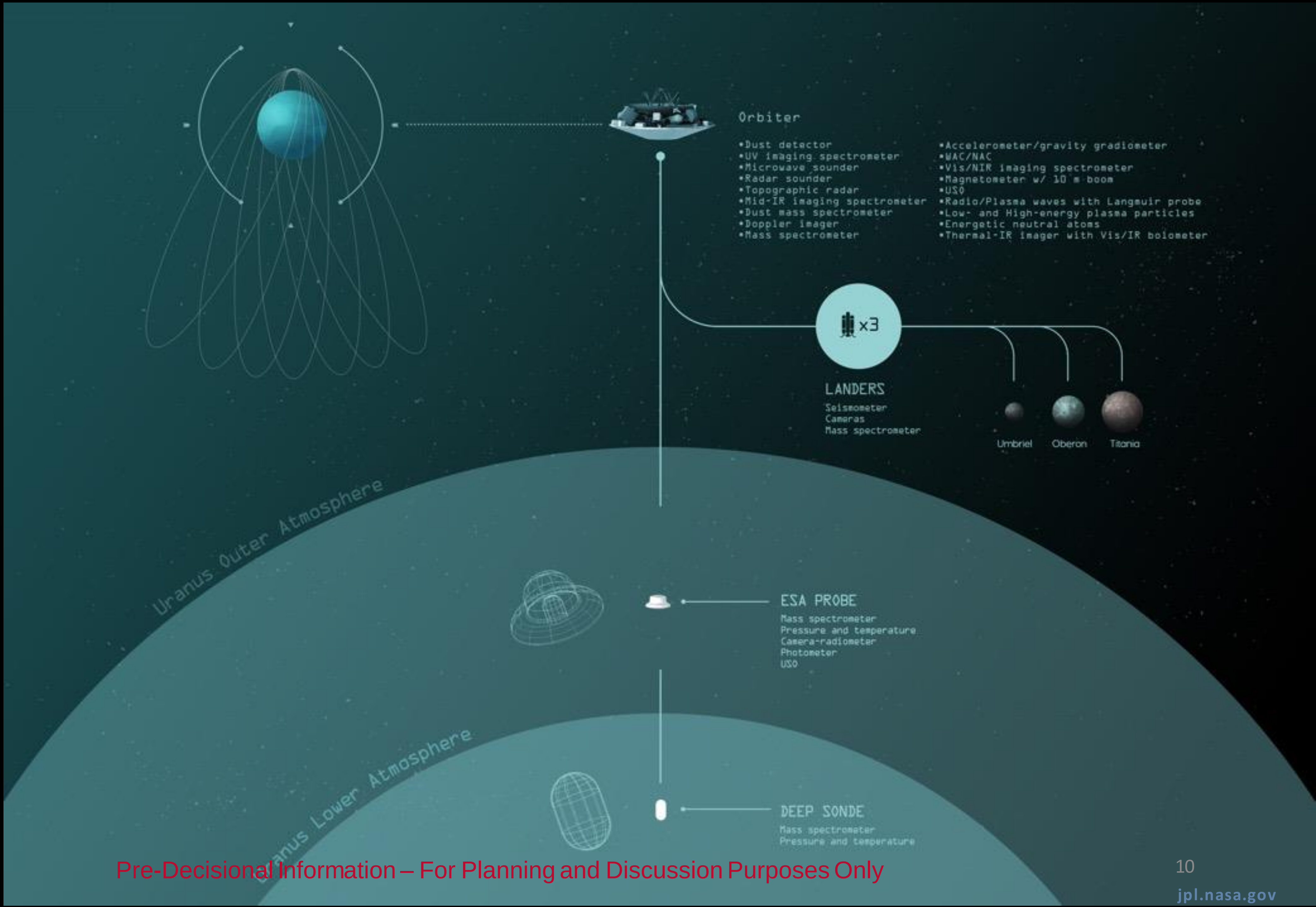
Stowed

Deployed

Smart Moon Landers
dropped on 3 moons

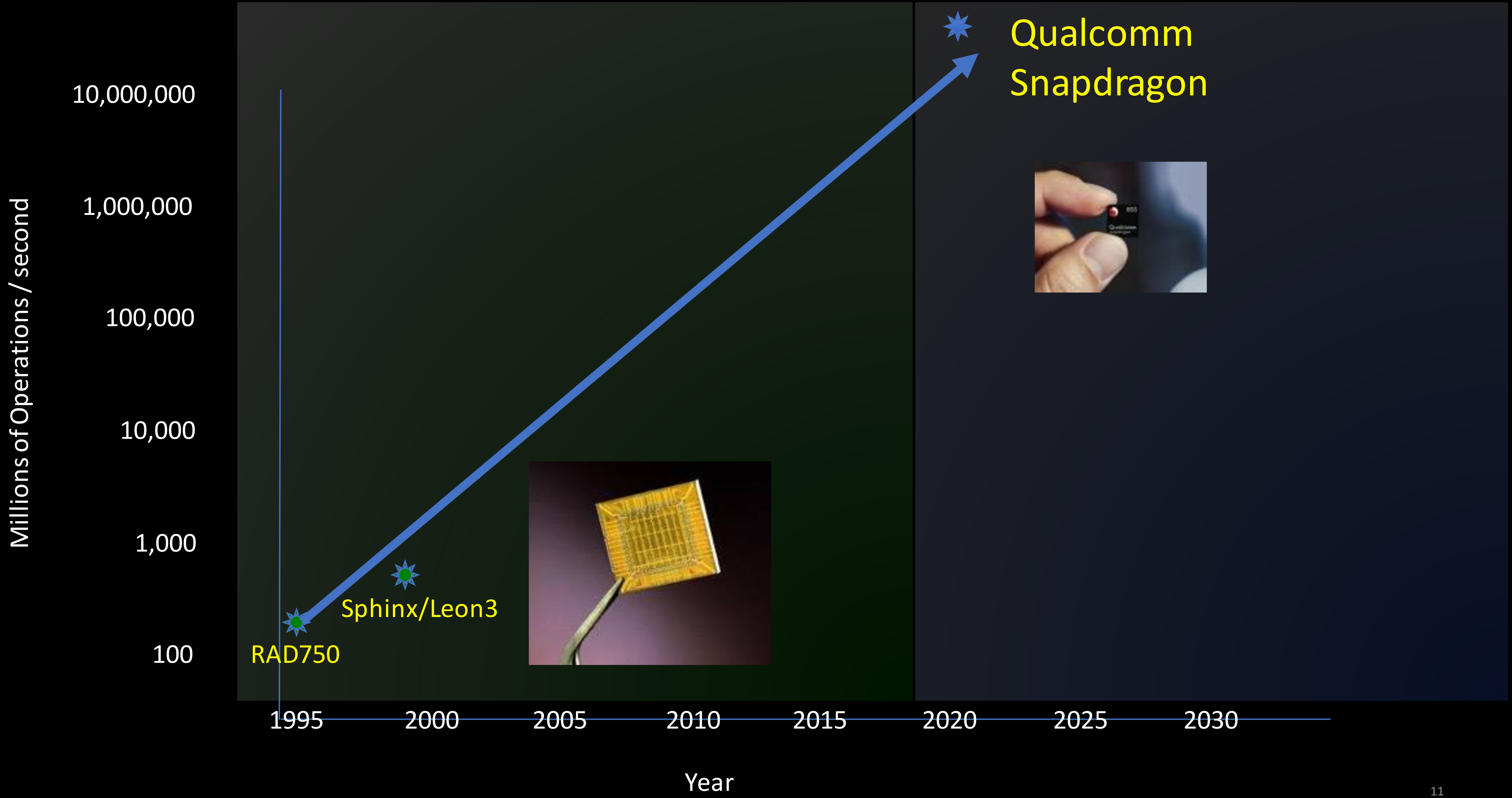
- Autonomous
- Seismometer
- camera

Uranus Tempest Mission Concept Overview



Pre-Decisional Information – For Planning and Discussion Purposes Only

High Power Processor Enables Tempest Autonomy



Uranus Tempest – the first autonomous mission concept!

Using an ultrapowerful processor, such as Qualcomm Snapdragon would allow Uranus to become the first fully autonomous concept mission

- 15 science instruments onboard adjust science priorities and optimize science collection
- Real time science operations to factor resources, science collection and spacecraft engineering performance including use of consumables
- On board hazardous environment analysis and mitigation
- Autonomous OpNav
- Autonomous landers and probes
    - Landing site selection
    - Autonomous descent and landing
    - Hopping
    - Deep Probe to Shallow Probe to Orbiter communications

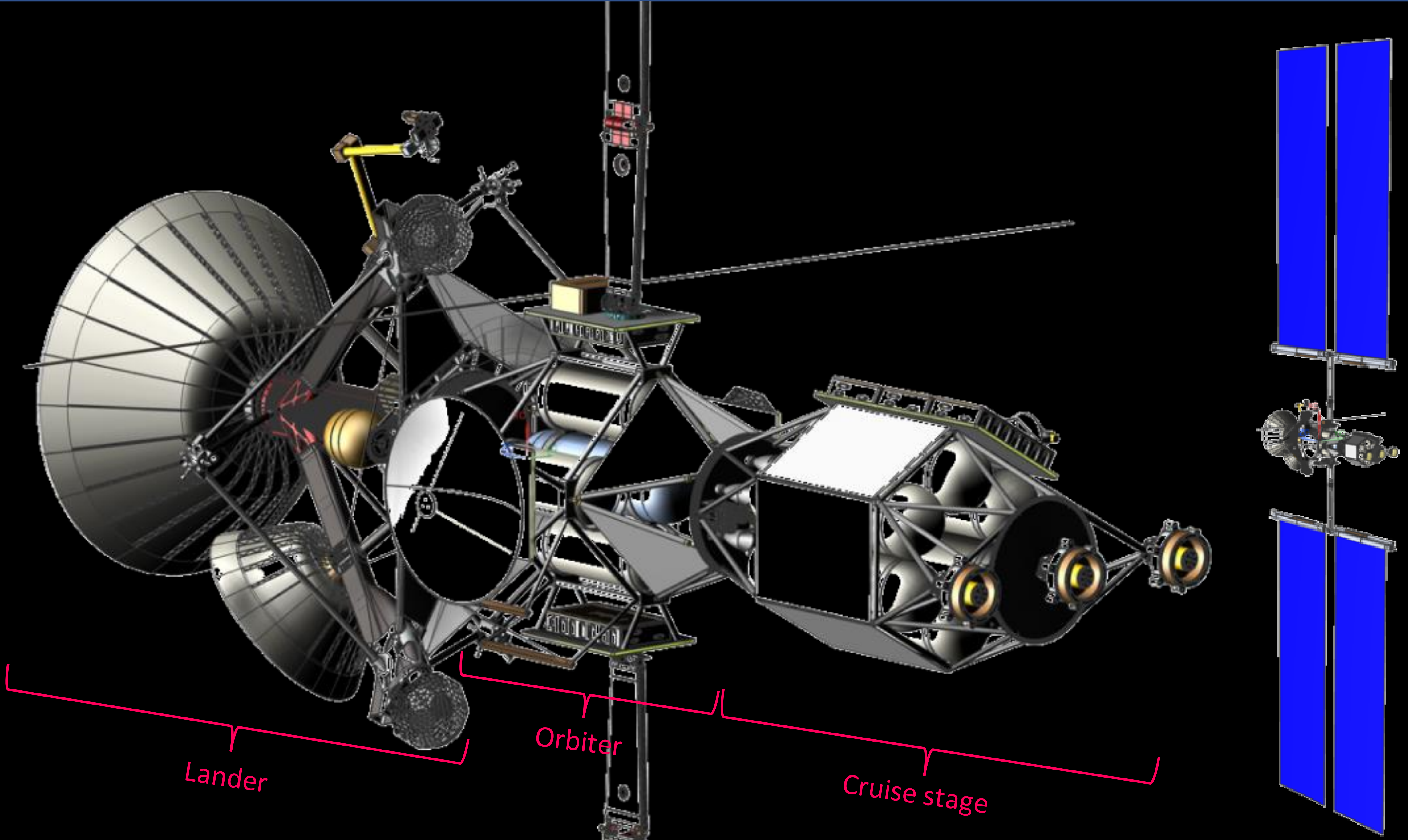
Uranus Tempest New Technology

- Aerocapture
- Nuclear electric propulsion
- MMRTGs
- Next generation small science instruments
- Autonomous spacecraft

Uranus Tempest Summary

- It is possible to design a flagship concept mission for uncompromised science at Uranus:
  - 15 science instruments
  - 3 small moon landers
  - shallow and deep atmospheric probes
- Falcon 9 class launch vehicle
  - Trip time reduced from 13 years to 9 by aerocapture
  - 2 years at Uranus
  - Nuclear electric propulsion allows moon landings and ring skimming

Study #2: **ENCELADUS**



Lander
Orbiter
Cruise stage

How to achieve these objectives?

Multi-element architecture is best suited to accomplish science objectives

Orbiter

- Characterize the surface (high-res topo, composition)
- Characterize the ice shell (thickness vs. location)
- Select landing site (thin ice region, active, safe to land)

Melt Probe

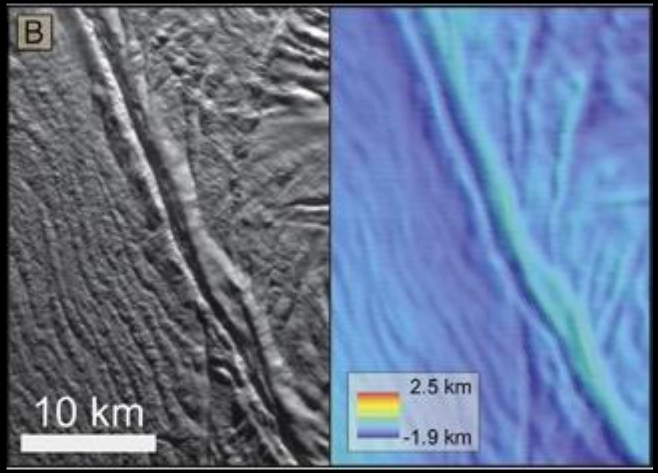
- Deployed, self-powered (RPS)
- Transits through ice shell in a few years
- Analyzes melt water on the way for full chemical composition and traces of past/extant life

Lander

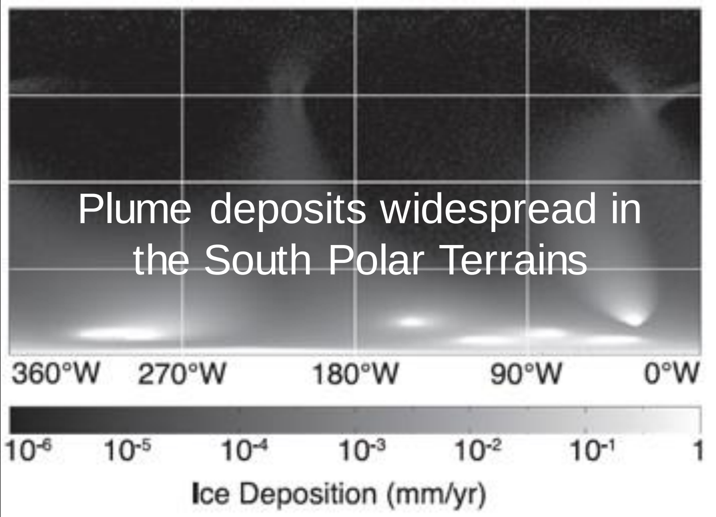
- Sample surface materials for analysis (biogenic markers, possible life if “revivable”)
- Descent, mechanical, power, telecom support for other landed elements

Vent Explorer

- Deployed from lander
- Transits to vent and crawls in it
- Conducts subsets of the analyses needed
- (Assessment of measurements feasible vs. needed in progress)



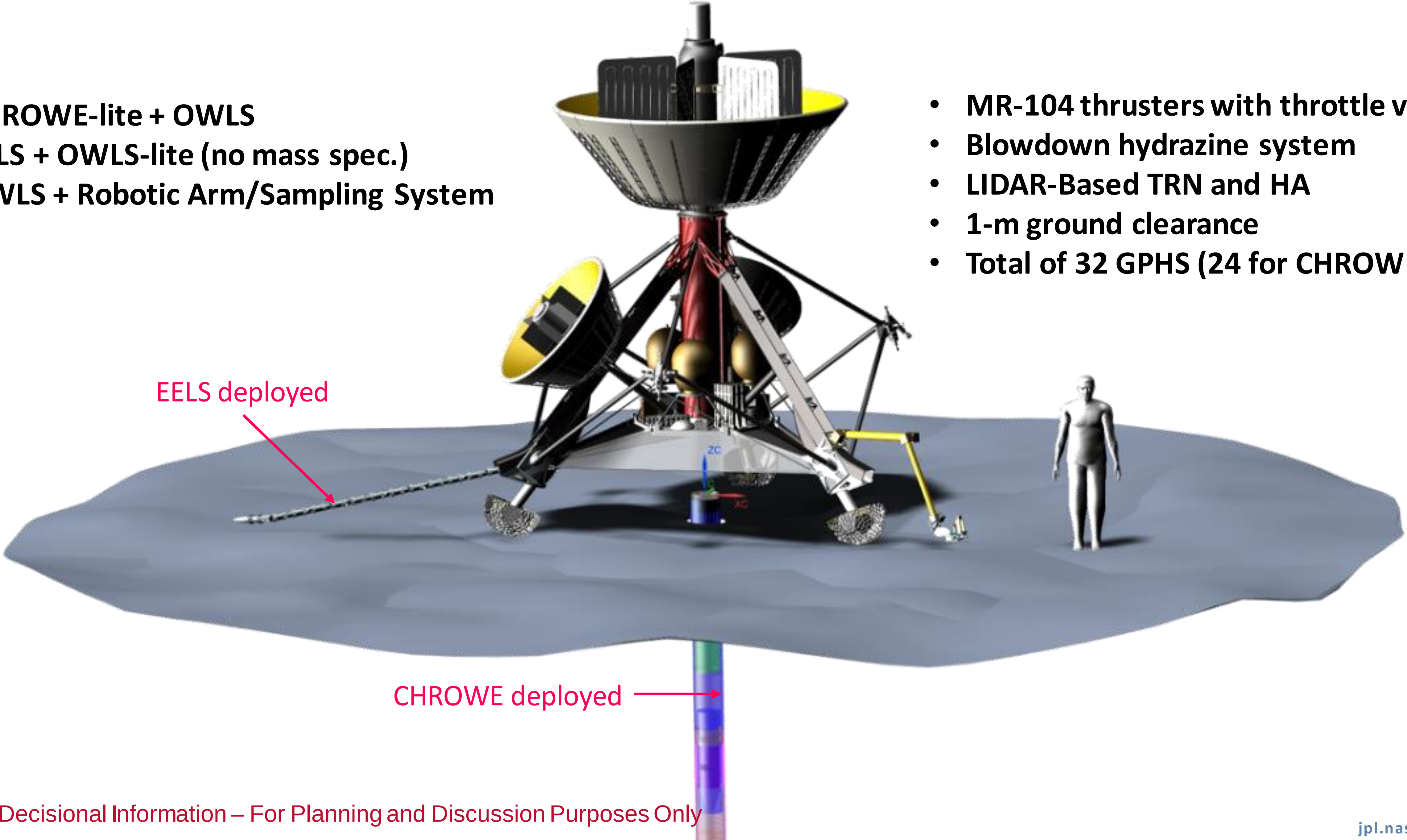
Tiger Stripes are wide enough to land within

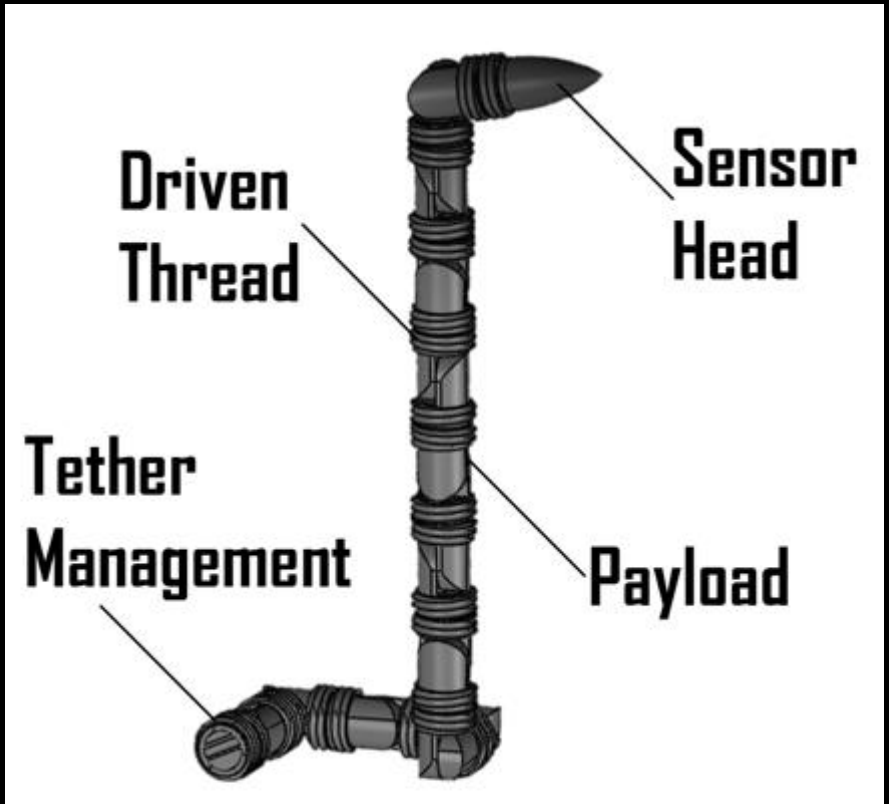


Fresh plume deposits are available at the surface

1 CHROWE-lite + OWLS
3 EELS + OWLS-lite (no mass spec.)
1 OWLS + Robotic Arm/Sampling System

- MR-104 thrusters with throttle valves
- Blowdown hydrazine system
- LIDAR-Based TRN and HA
- 1-m ground clearance
- Total of 32 GPHS (24 for CHROWE)

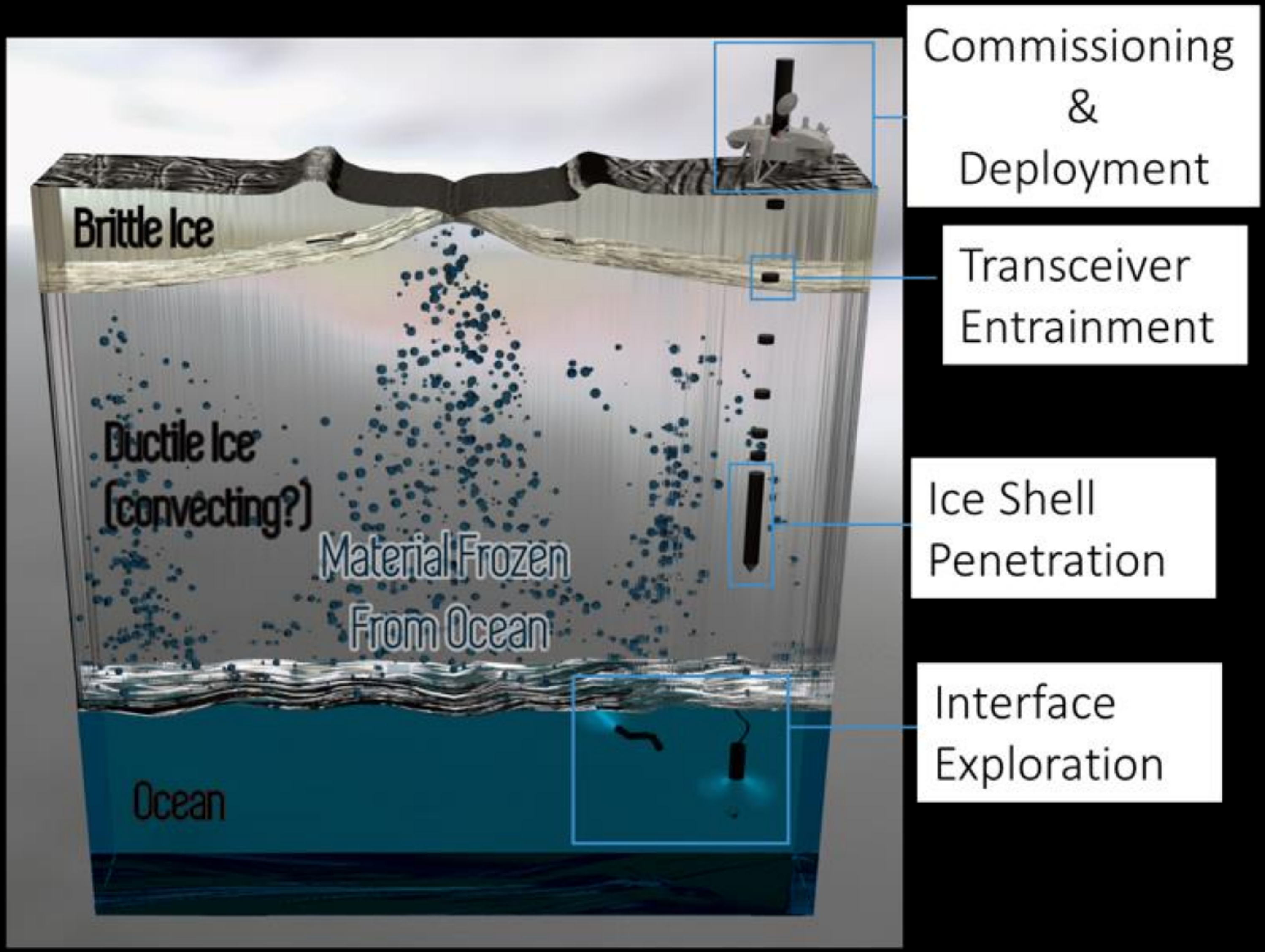



Driven
Thread
Sensor
Head
Tether
Management
Payload

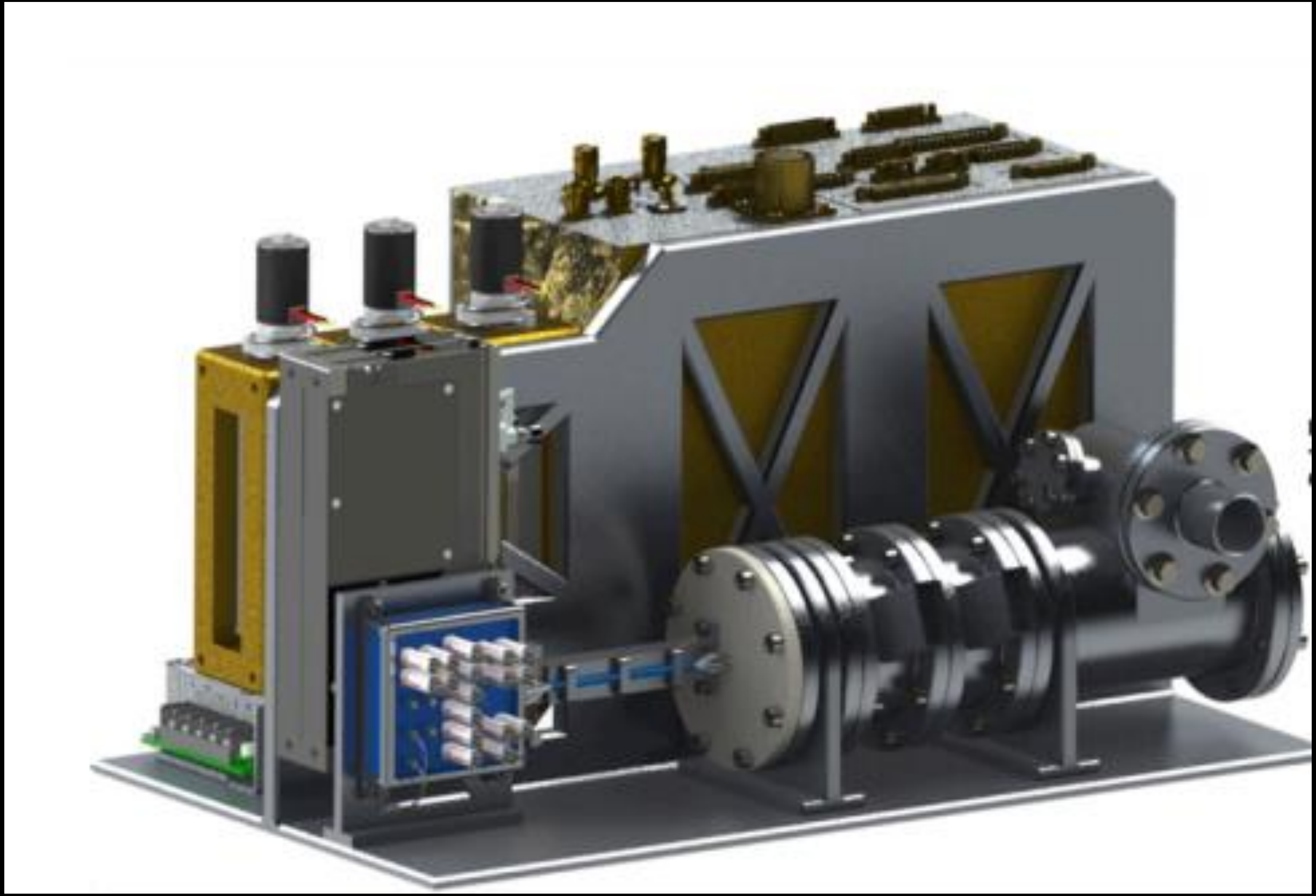

EELS
EXO-BIOLOGY
EXTANT
LIFE SURVEYOR

CHROWE

Cryo-Hydro Robot for Ocean Worlds Exploration



OWLS -Ocean Worlds Life Surveyor



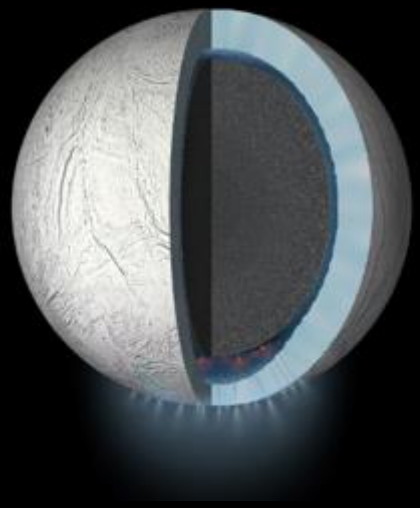
Pre-Decisional Information – For Planning and Discussion Purposes Only

Enceladus Science Objectives

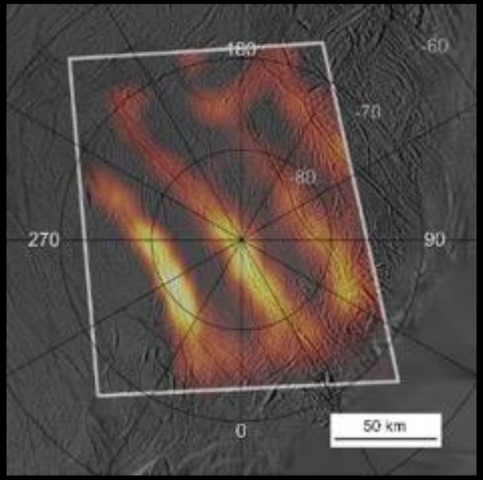
- <u>Singular Goal is To Search for Evidence of Life</u>
  - Accessible habitable environment!!
  - Requires ocean samples, multiple measurements (context / validation / multiple techniques)
  - Search for organic molecules, biogenic vs. abiotic, chirality of amino acids, fragment of membranes (lipids), functional molecules for biochemistry, potential cells (extant life)

- Supporting Objectives
  1. Determine the conditions (T, pH, composition, etc.) of the ocean
  2. Understand the history of Enceladus and its ocean

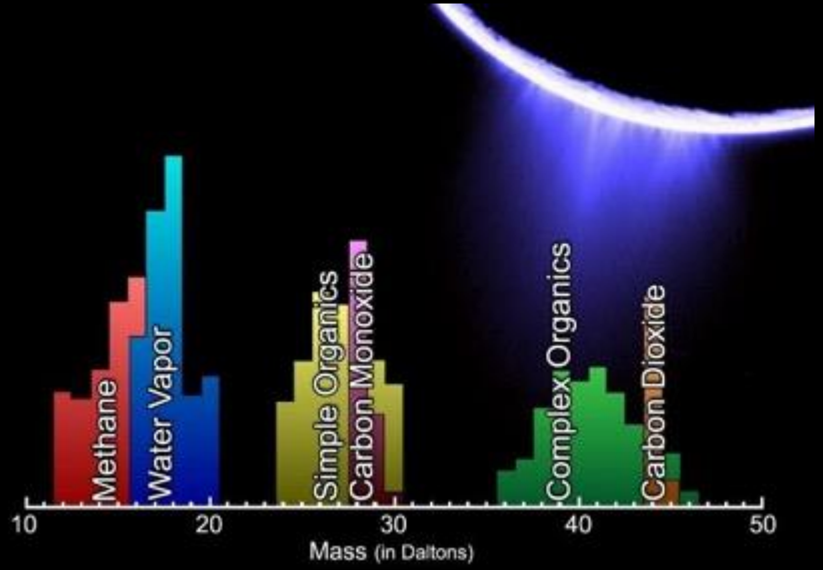
Global ocean and plumes



Lots of heat!



Organic compounds, CO_2, high pH, H_2

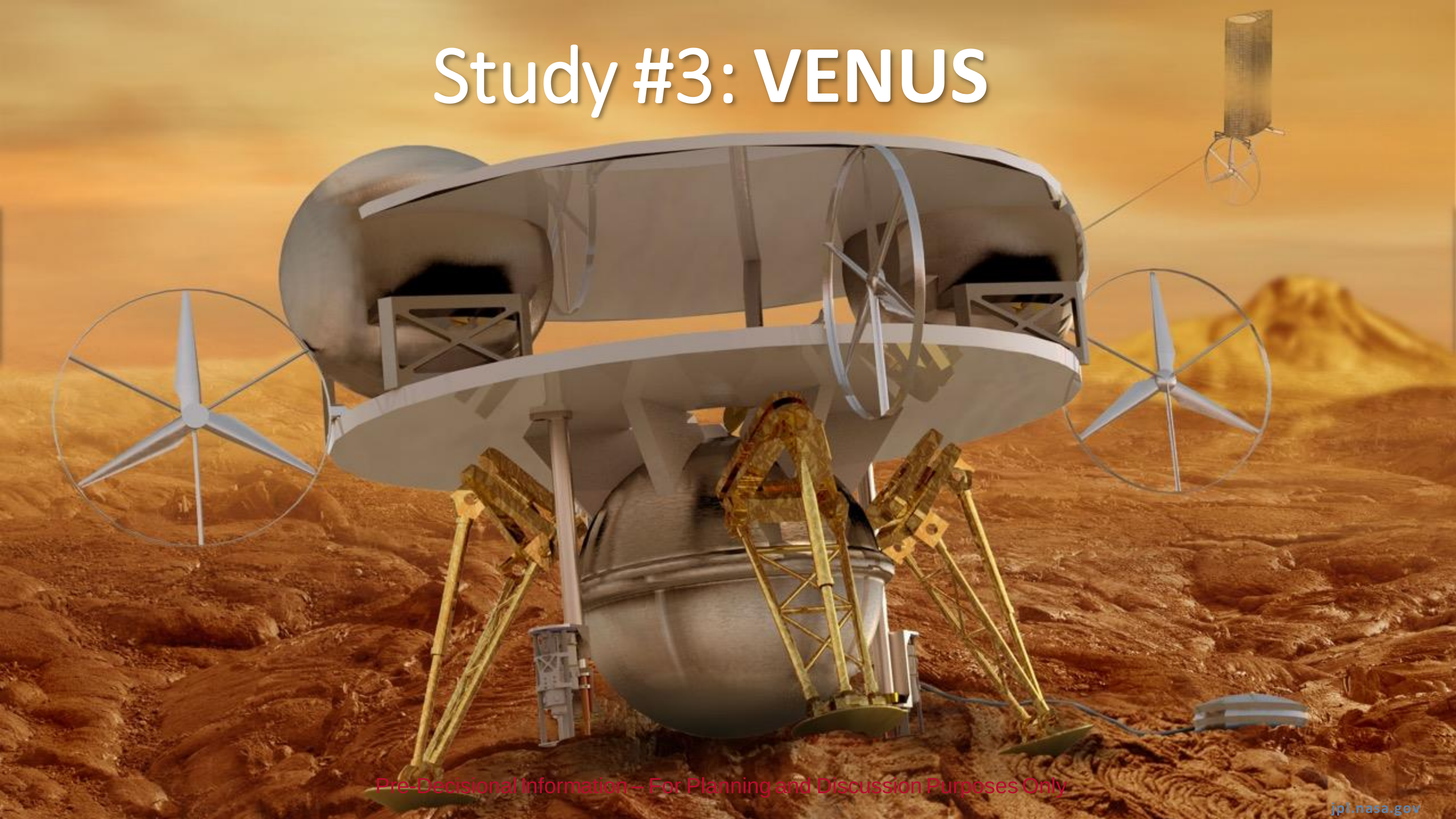


Enceladus Mission: Conceptual Flight System

Summary

- A flagship mission concept to search for evidence of life in unaltered samples of Enceladus' subsurface ocean may be feasible for consideration in the next planetary science decadal survey.
- The Enceladus-Ark mission concept would deploy both adaptable multi-terrain robots (EELS) that navigate down erupting vents and an intelligent melt probe (CHROWE) for direct ice shell penetration; both would carry an instrument suite (OWLS) to search for evidence of life in samples acquired during descent and within the ocean.
- Winter at Enceladus' south polar region drives instruments and subsystems but may not drive the mission architecture.

Study #3: VENUS



Proposed Mission Concept Solution

- Partitioning of science by technology and lifetime requirement
  - Complex instrumentation feasible only with conventional electronics – short lifetime (less than 6 hours)
  - Instrumentation requiring long time baseline (seismology meteorology – long life time
- Precision and safe landing system
  - Lander descend under parachute to limit rate of descent
  - Terrain relative navigation used to locate landing stie
  - Rotors are used for lateral control to propel the vehicle to the desired lsite
- Power generation
  - Wind turbine is lofted from the lander using a metallic balloon
  - Power generated is conducted down the tether to the lander
- Innovative thermal control
  - Takes advantage of mature silicon on oxide electronics operating to 250C.
  - Refrigerator heat pump powered by the turbine can achieve these temperatures in the Venus environment

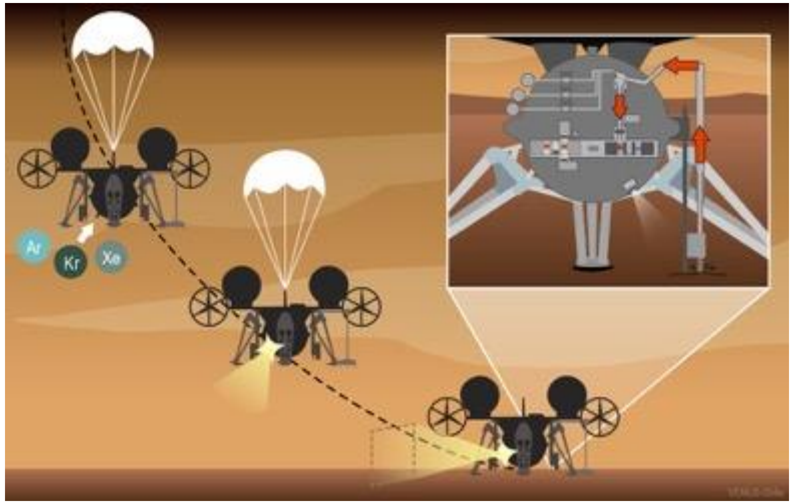
Venus Science Objectives

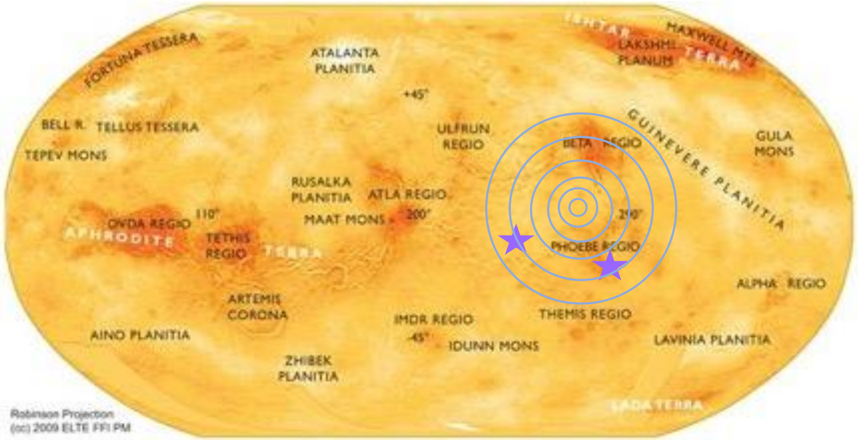
Short Duration Measurements- achievable during descent and several-hour surface mission concept

- Geochemistry/Mineralogy of surface materials
- Sampling and sampling w/depth by drilling
- Atmospheric sampling & imaging during descent
- NIR/Vis imaging to tie to global data
- Noble gases for formation/volatile history
- Active chemical species (SO_2, halogens), cloud properties

- Long Duration Measurements - at least 1 Venus year -243 Earth days
  - Broad band seismology for interior structure, tectonic processes
  - Heat flow , surface temperature
  - Meteorology: winds, gas composition –volcanic outgassing?

How to Achieve Science Objectives?



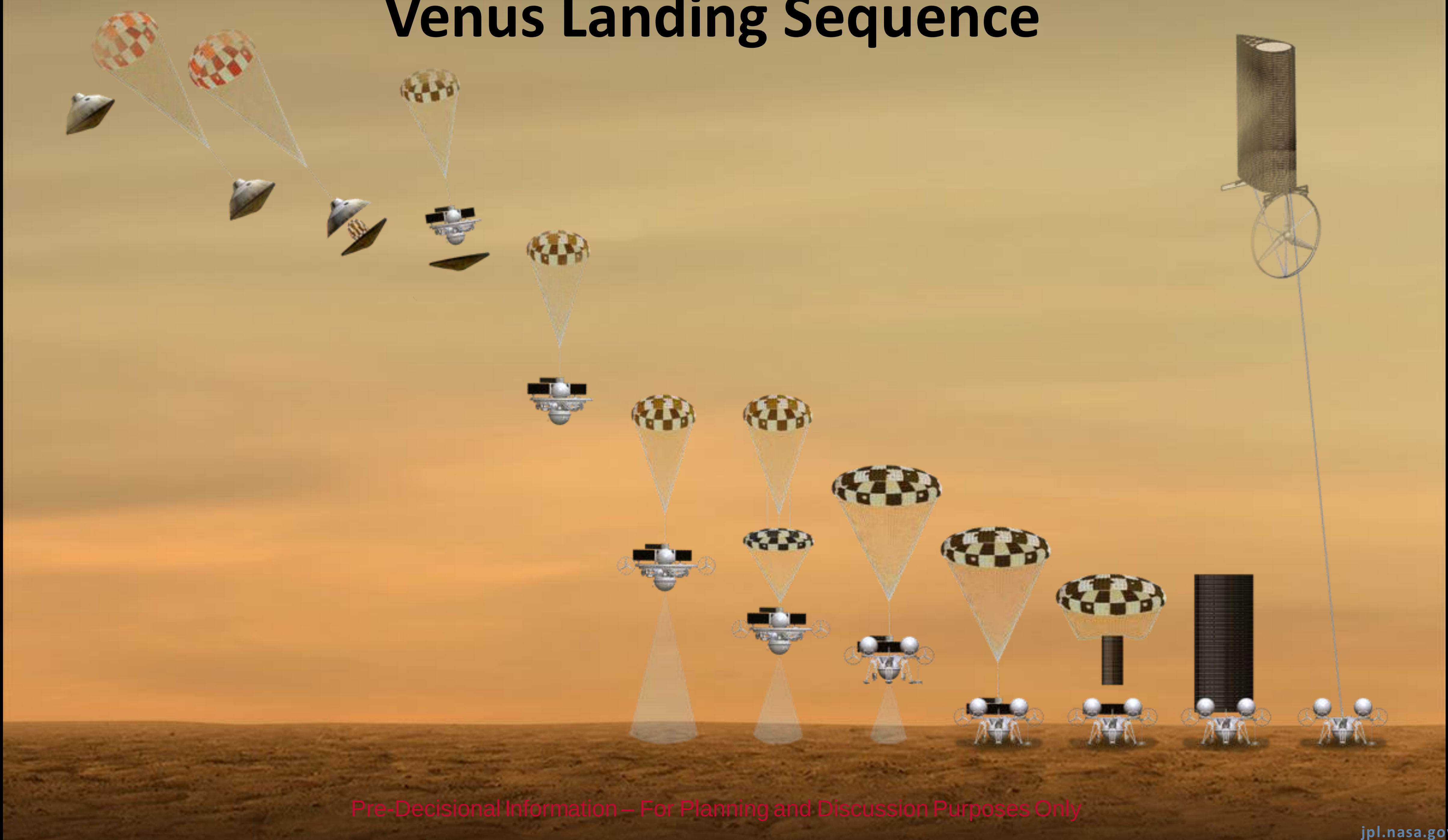


Multi-month seismic and weather measurements enabled by lofted wind turbine power generation.

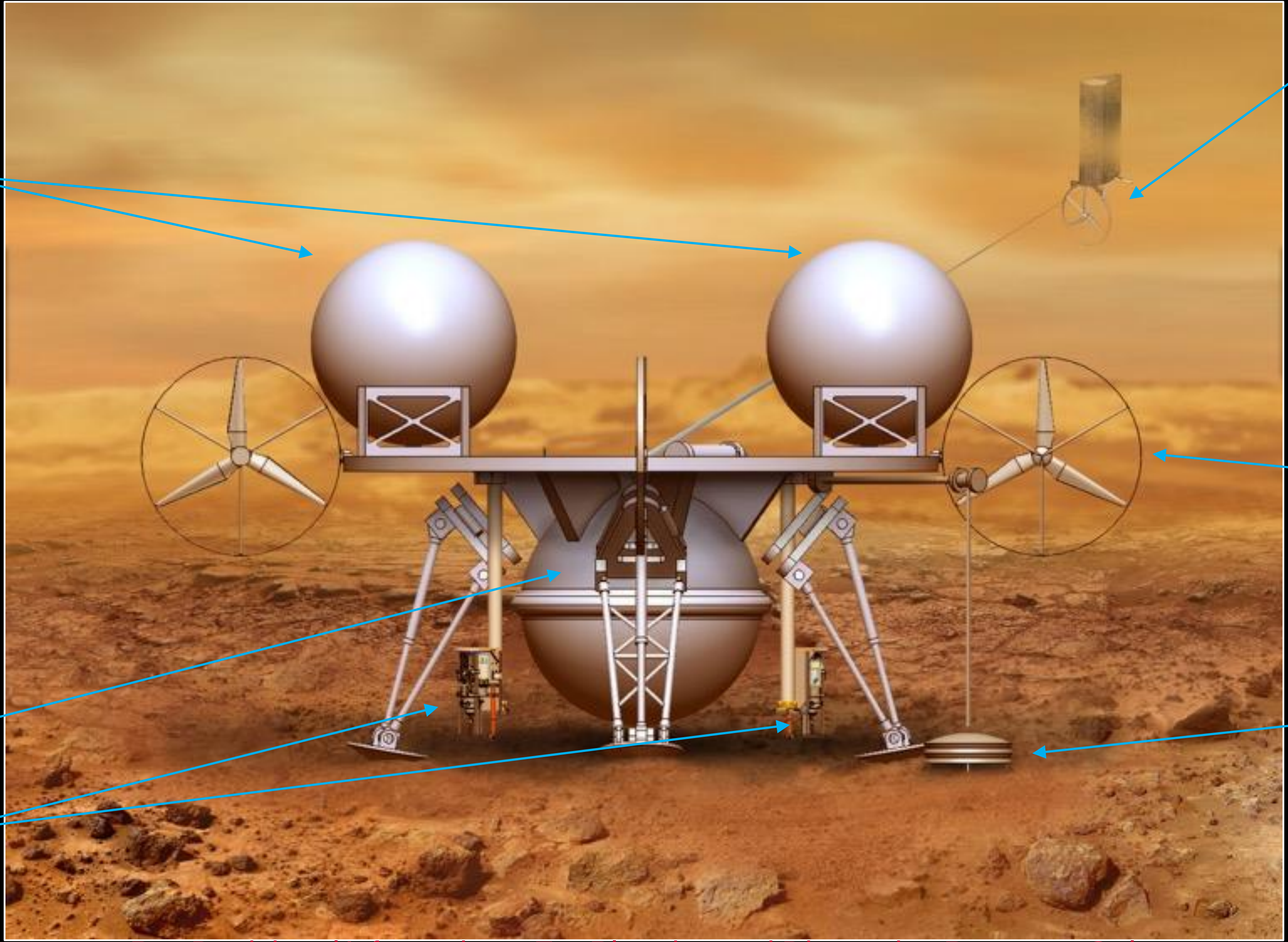
Short-lived vehicle elements conduct comprehensive atmospheric and geochemical investigations.

Multi-lander architecture enables investigation of tesserae and plains and greatly enhances seismic investigation.

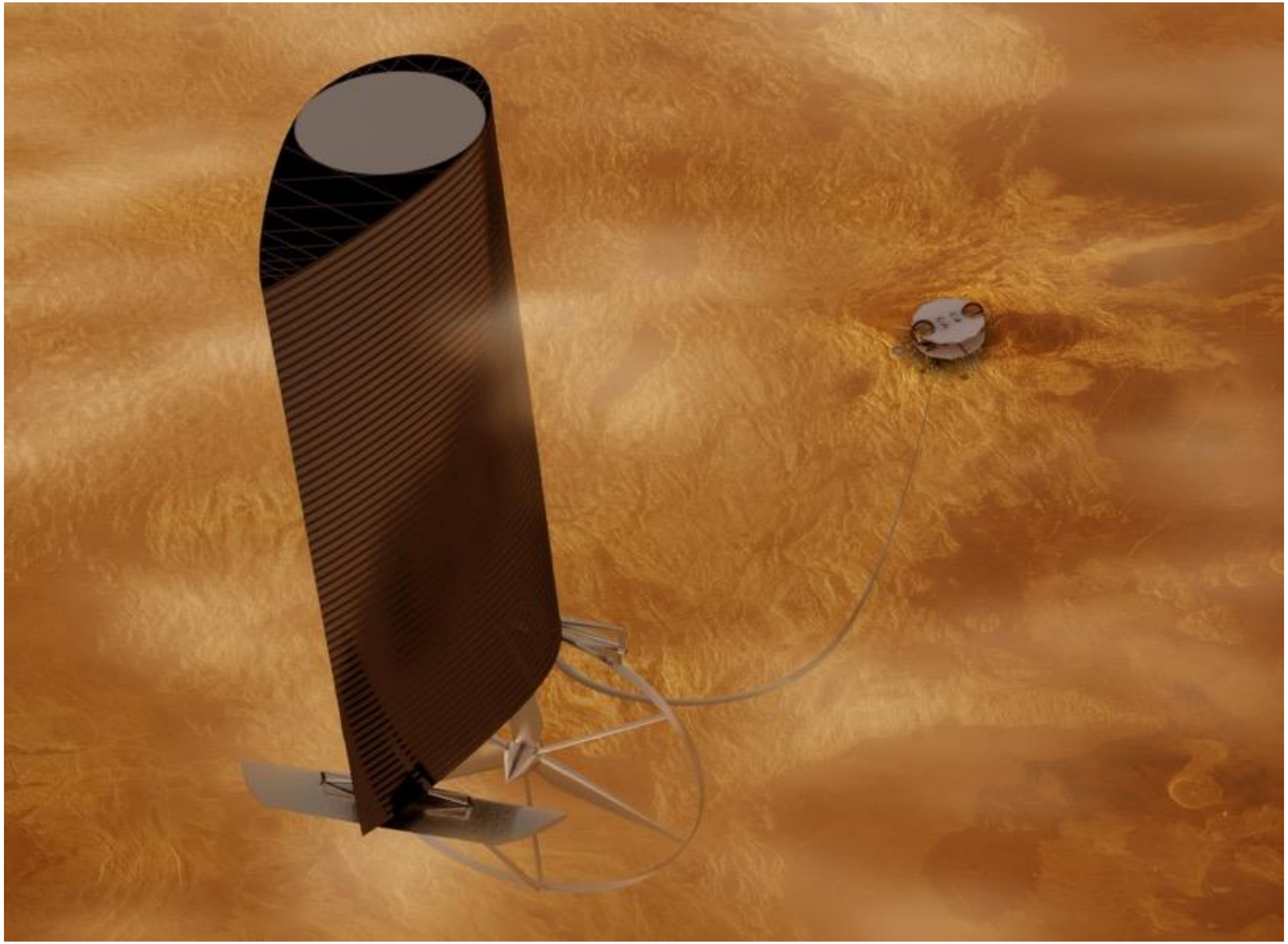
Venus Landing Sequence

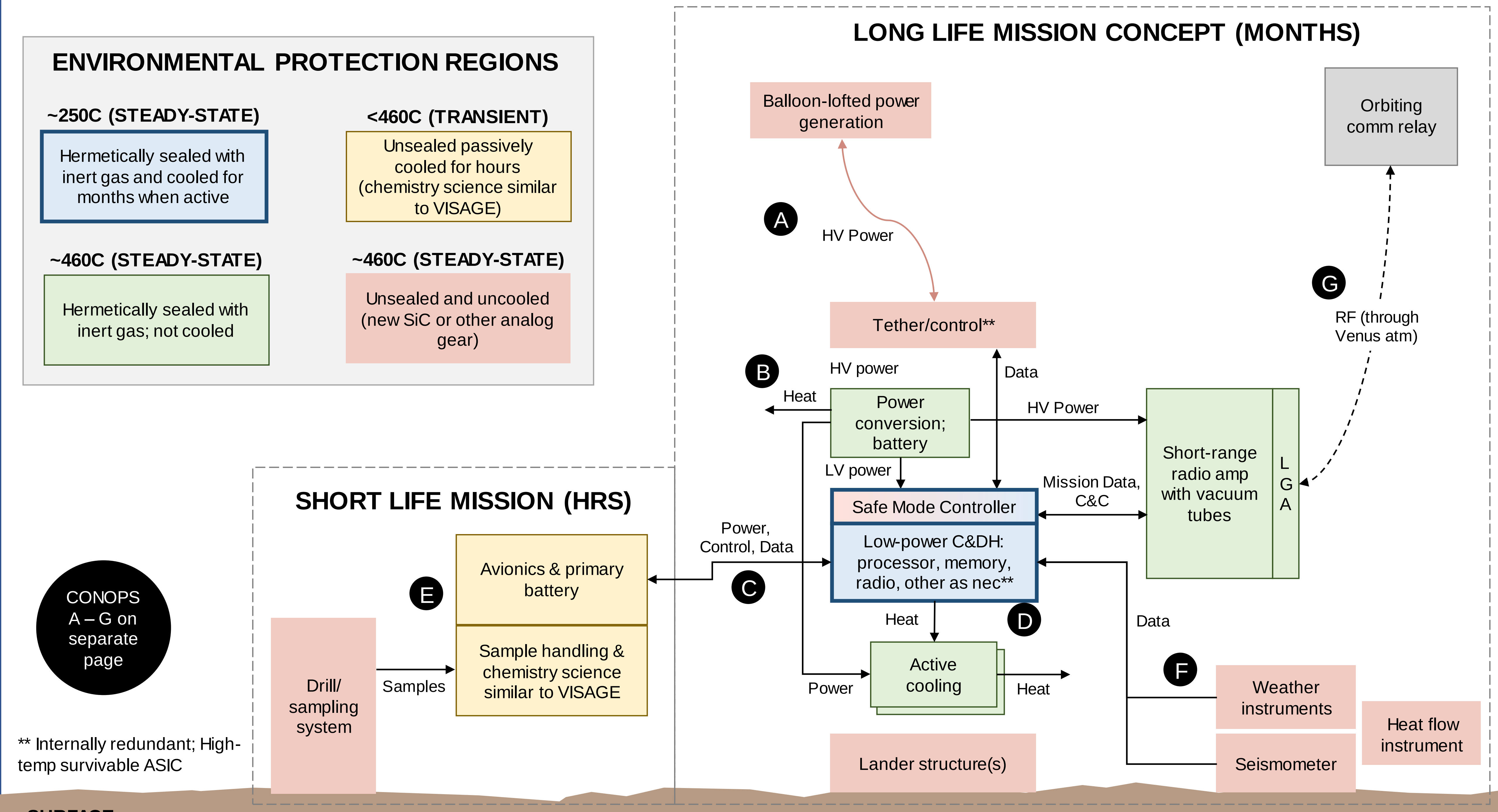


Lander configuration Baseline



Wind Turbine





ENVIRONMENTAL PROTECTION REGIONS
~250C (STEADY-STATE)
Hermetically sealed with inert gas and cooled for months when active
<460C (TRANSIENT)
Unsealed passively cooled for hours (chemistry science similar to VISAGE)
~460C (STEADY-STATE)
Hermetically sealed with inert gas; not cooled
~460C (STEADY-STATE)
Unsealed and uncooled (new SiC or other analog gear)
LONG LIFE MISSION CONCEPT (MONTHS)
Balloon-lofted power generation
Orbiting comm relay
A
HV Power
Tether/control**
G
RF (through Venus atm)
B
HV power
Data
Heat
Power conversion; battery
HV Power
Short-range radio amp with vacuum tubes
L G A
LV power
Mission Data, C&C
Safe Mode Controller
Low-power C&DH: processor, memory, radio, other as nec**
SHORT LIFE MISSION (HRS)
Power, Control, Data
Avionics & primary battery
E
C
D
Heat
Data
Sample handling & chemistry science similar to VISAGE
Drill/ sampling system
Samples
Active cooling
Power
Heat
F
Weather instruments
Heat flow instrument
Seismometer
Lander structure(s)
CONOPS A – G on separate page
** Internally redundant; High-temp survivable ASIC
SURFACE

Summary

Venus surface exploration presents formidable challenges

- High temperatures - up to 460C
- High pressures – 90 bars
- Corrosive Environment – supercritical CO_2 and sulfur dioxide
- Lack of sunlight – highly restricted solar power.
- Complex topography - at the most interesting landing sites

This mission concept address those challenges with

- Partitioning of science objectives by technology and lifetime requirement
- Precision landing
- Generation of power from near surface winds
- Innovative thermal control systems

Jet Propulsion Laboratory
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